Atmospheric Support for Ground Systems Hit Avoidance Modeling Effort

Scarlett Ayres, **Robert Sutherland**
U.S. Army Research Laboratory
Survivability Lethality Analysis Directorate
White Sands Missile Range, NM 88002-5501

Abstract

The Army Research Laboratory Survivability Lethality Analysis Directorate (ARL/SLAD) has identified for system analysis studies the need for high fidelity computer simulations of realistic battlefield environments requiring correspondingly high fidelity met/atmospheric input not currently available from conventional databases. The need spans (most) all SLAD mission areas. In August 1997, the Tools, Techniques, and Methodology (TTM) effort "Atmospheric Support for Ground Systems Hit Avoidance" was formed. The purpose of this group was to develop high fidelity meteorological/obscurant models in the FY98 and FY99 timeframe to be used in the missile warning systems models for ground systems survivability studies. These models will be used to develop the capability to predict/simulate effects of obscured atmospheres on propagation of laser beams and missile plume signatures for ground system defensive aids. The overall TTM effort consists of integrating several existing models; the Vehicle Smoke Protection Model (VSPM), the Combined Obscuration for Battlefield Contaminants (COMBIC), the MODerate resolution Transmission code (MODTRAN), and the Missile Flyout Model (FLYOUT), with several models to be developed; the Diurnal Scale Met Characterization Model (DAY24), the Missile Signature Propagation Model (MSPROP), and the Laser Propagation Model (LASPROP). The DAY24 Generator Model will provide the full diurnal-cycle and high-resolution vertical profiles (wind speed, temperature, relative humidity) of critical atmospheric/meteorological parameters for up to 16 stability categories and 22 adverse weather types. LIDAR measurements and met measurements taken via met towers and tetherballoons will be used to develop the model. The obscurant models will be run to compute transmittance and concentration data for selected battlefield munitions. The data will be used to develop an analytical tool for the systems analyst to evaluate the effectiveness of various defensive aids. MSPROP combined with the missile FLYOUT model will take missile signature data and compute the missile signature as seen by a Missile Warning Receiver (MWR) through weather and obscurants. LSPROP will propagate the signal from a laser designator through weather and obscurants to calculate the resultant scattering into a Laser Warning Receiver (LWR).

19981029 101

1. Introduction

Figure 1a presents a flowchart for the TTM effort to propagate a missile signature through the atmosphere, smoke and dust to a MWR. The primary input for this effort is the measured missile plume signature data corrected for the atmospheric losses computed for the site in which the signature data was measured. The purpose of this TTM effort is to calculate how this data would change based upon site-specific met conditions and battlefield obscurants. The

DTIC QUALITY INSPECTED 4

analyst will choose a specific location, time of day, wavelength(s) and pull from a met data base the parameters needed to prime the DAY24 Generator model. The DAY24 Generator model will then produce the vertical profiles of wind speed, temperature, pressure and in some cases aerosol concentration to be fed into MODTRAN, MSPROP and COMBIC/VSPM. MODTRAN will use these vertical met profiles to determine atmospheric losses for the Lines of Sight (LOS) from the tank to the missile. The FLYOUT model is used to compute the position (i.e. LOSs). MSPROP role is to access the FLYOUT model position calculations, access the DAY24 Generator vertical profiles of wind, temperature and pressure and compute the missile plume signature, also, taking into account the atmospheric losses computed by MODTRAN for the site, season and time of day the user has chosen. COMBIC/VSPM is then run for a smoke scenario developed by the user and for the met parameters computed by the DAY24 Generator model to compute the effects of smoke and dust on the LOSs. The modified missile plume signature computed by MSPROP is then further modified by the obscurant degradation computed by COMBIC/VSPM to compute the signal that would enter the MWR. The analyst can feed this modified signature into existing simulations such as Hardware In the Loop (HWIL) simulations or use a MWR model to determine the effects of smoke, dust and the environment on the MWR ability to acquire the missile, determine range to missile, and determine type of missile. This information will drive the selections of the counter-measures (self-defense smoke grenades, IR decoys, jammers, or vehicle movement) to be deployed.

The TTM effort to propagate a laser signal through the atmosphere and obscurants to the LWR is structured fairly similar to the missile plume signature propagation effort. The major difference is a Laser Designator Driver model to compute the laser designator's signal instead of using measured missile plume signature data. The model is capable of providing both the directly transmitted radiation and multiple scattering from all directions inside an obscurant cloud. It computes the interaction of photons with obscurant particles to produce scattering, absorption, and emission. It offers the potential for high fidelity results. Photons could be traced to examine particular aspects of the propagation of a laser designator signal, or the model could be run to compute only those photons that arrive at a certain location such as a LWR aperture. However, the Laser Propagation Model main function is to propagate the laser signal through the atmosphere and through obscurants to a LWR. The effort for fiscal year 98 is to complete a working model for a simple fogoil obscurant.

Another TTM effort that SLAD is developing models the reverse problem of the missile acquiring the target (Anderson, et. al., 1998). These developers are creating a scene based model that will integrate various sub-models together to form a more productive tool to analyze the obscurant impact on a missile's ability to detect a target. Both efforts can eventually be used to as tools to refine Commander Decisions Aids (CDAs). The CDAs will help the commander decided when to use smoke or decoys, when to attack and when to maneuver. Factors driving CDAs are detection range, time to detect, time available to respond, determination of type of missile or laser designator, and countermeasures available.

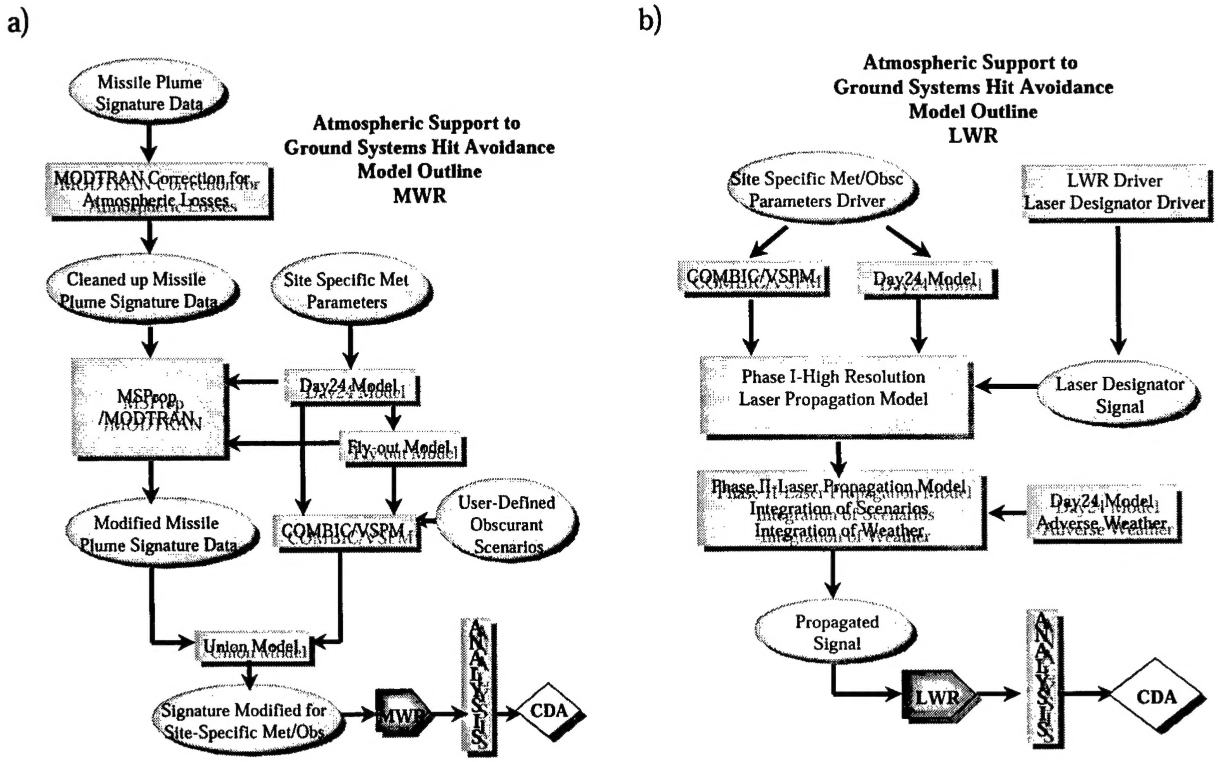


Figure 1a-b Flowchart diagram for a) model to propagate missile plume signature to a MWR and b) model to propagate laser designator signal to LWR.

2. Measurements/Data

Meteorological measurements such as wind speed, temperature and humidity will be intensively collected in the spring, 1998. This data will be used to support the development of the DAY24 Generator model. Site specific met parameters will be determined for four sites of interest by accessing weather databases. DAY24 will read in this data for the four sites and expand the data to create a full-diurnal cycle.

2.1 Meteorological Data

2.1.1 Methodology

LIDAR data and met data will be collected in order to develop the DAY24 Generator model's ability to generate full-diurnal cycle characterization of critical atmospheric/ meteorological parameters. The type of data to be measured is; windspeed, sensible heat flux, mixing height, concentration of aerosols, net radiation, relative humidity, temperature (1 m, 10 m, 38 m), soil temperature (0 cm, 10 cm, 40 cm and 1 meter), and surface temperature. This data will be collected via instrumentation packages attached to towers and with the LIDAR in late spring of 1998 for a month to cover the 16 possible atmospheric stability categories. Surface and profile measurements will be made primarily at sunset, sunrise and midday. Sunset and sunrise are the times when the met parameters experience the most change. Midday is chosen to capture

the "maximum" values of the met parameters. The met data will be used to compute the surface energy balance budget.

2.1.2 LIDAR

The LIDAR transmits laser light, which is scattered off of air molecules, cloud droplets and aerosols in the boundary layer. The returned light is collected in a telescope and focused on a photomultiplier detector and then amplified, digitized, and recorded. The LIDAR can provide water vapor profiles and aerosols profiles and mixing height. A single-wavelength LIDAR system (DRC11-3 YAG laser, 355 nm) will be used to measure the extinction due to absorption (ozone) and scattering (Rayleigh + aerosol). For the slant or vertical path measurement we will be using an upper and lower bound extinction boundary condition given by the LIDAR signal (slope method) and Rayleigh scattering respectively. The laser runs at 10 Hz, and an average of 1000 laser shots is taken. The process lasts about 2 minutes of data gathering. Knowledge of the extinction profile is available within 15 minutes. The receiver and transmitter is near collinear with the crossover occurring at about 200 meters. Vertical resolution is about 1 meter. An example of the extinction profile is shown in Figure 2. Note that the mixing layer height is clearly evident at 4000 meters.

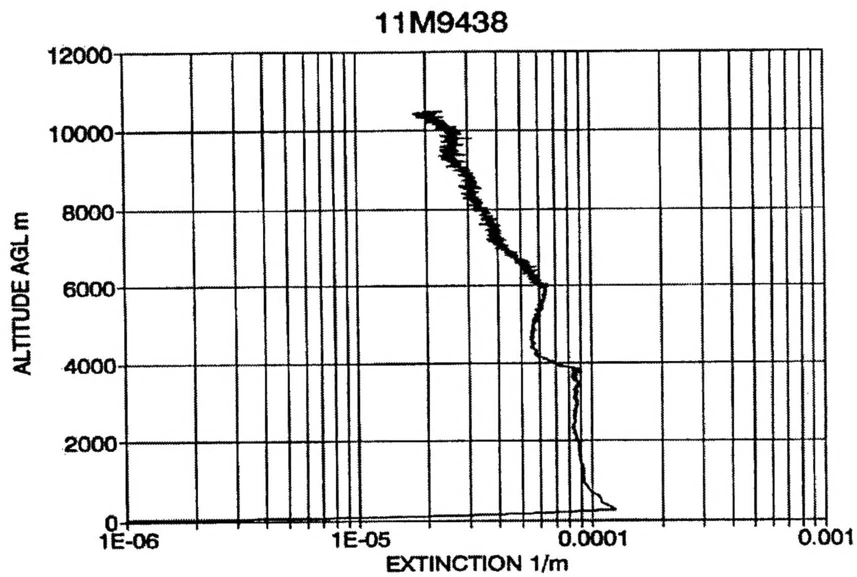


Figure 2 LIDAR data showing extinction vs. altitude for a typical boundary layer atmosphere

2.1.3 Met Instrumentation

Meteorological measurements in support of developing the Day24 Generator model will be collected at the ARL/SLAD Tower site located at White Sands Missile Range (WSMR), NM. The site is located in the Tularosa Basin, southeast of the post area. The elevation of the site is ~1220 m MSL (mean sea level) and is characterized by low desert brush and grasses. Mean and

turbulent meteorological data is collected for several hours in the morning, noon and evening in order to acquire data for all possible atmospheric stabilities. Met data is collected via two sources: one being the standard range support at the range "C" station and the other is specialized local measurements. Met data will be collected at 1 m, 10 m and 25 m. A tethersonde will be used (wind conditions permitting) to collect data up to 1 km. The tetherballon is an aerodynamically shaped helium-filled plastic balloon that is tethered to a winch on the ground. Instead of being blown down-range by the wind, the shape allows it to soar upwards. A met sensor package is suspended a short distance below the balloon on a line different from the tether line. To make measurements at a variety of heights, the winch is used to draw in or feed out more line until the desired height is reached. The balloon is kept at each height of interest for 30 minutes to get a statistically stable sample, before changing its altitude. Also, the balloon can make measurements while it is rising or descending, allowing soundings to be recorded. These balloons are limited to light winds. The tethersonde will be used to acquire temperature, humidity, pressure and windspeed at 200 and 1000 meters. Deployment of other sensor instrumentation is as follows:

- 5103's - Wind Direction and Wind Speed (2 each at 35m, 10m altitude)
- Rotronics(2) - Temperature & Relative Humidity = (2 each at 35m, 10m altitude)
- Thermocouple - Soil Temperature (2 each at surface, and 10cm, 40cm and 1m below surface)
- Infrared Temperature Transducers – Surface Temperature (direct exposed surface & shaded surface)
- Pyronameter - radiation (2m level)
- Air Barometer - pressure (1m level)

The two weatherproof infrared temperature transducers are used to determine net surface radiation. The thermocouples are used to determine the heat transfer at the surface. The towers and tethersonde measurements of temperature, humidity, and wind fluctuations are used to determine fluxes.

2.2 Missile Plume Signature Data

The missile plume signature data was collected at a live-fire test by the Signature Measurements Group of SLAD (Cundiff, 1998). The data were collected with a variety of instrumentation including and infrared (IR) Fourier transform spectrometer (FTS), an IR thermal imaging system, and ultraviolet (UV) grating spectrometer, and a visible-to-near, IR grating spectrometer. The data were reduced as spectral apparent radiant intensity (data not corrected for atmospheric losses) and spectral radiant intensity (data corrected for atmospheric losses (MODTRAN)). Figure 3 shows an example of the missile plume signature data collected for 3-5 μm.

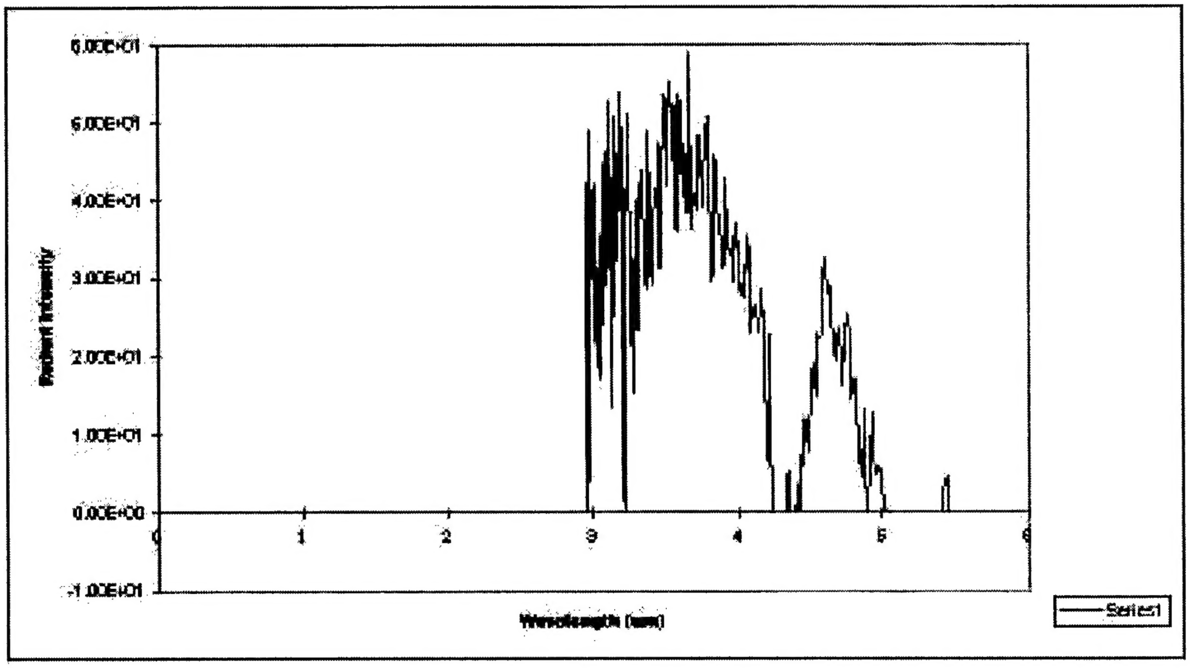


Figure 3 Missile plume signature data

3. Existing Models

3.1 COMBIC/VSPM

The COMBIC (Ayres and DeSutter, 1993) computer simulation predicts spatial and temporal variation in transmission produced by various smoke and dust sources. It models the effects of reduction in transmission by combining the munition characteristics with meteorological information of an idealized real world. COMBIC produces transmission histories at any of seven wavelength bands for a potentially unlimited number of sources and LOS. It also computes concentration length (CL)--the integration of the concentration over the LOS path. Phase I is run off-line to compute cloud histories for each specified munition. Phase II integrates the LOS over all clouds present on the battlefield to determine the CL and transmission. COMBIC uses a simple local area atmospheric boundary layer model where the wind field direction and horizontal windspeed profile are uniform and static everywhere in the scenario. Complex terrain and its effects on windfield is not modeled.

The Vehicle Smoke Protection Model (VSPM) (Johnson and Rouse, 1997) was developed as an augmentation to COMBIC by including certain higher aspects of smoke deployment systems. VSPM explicitly models dischargers locations and orientation on vehicles as well as the orientation of the vehicles on the battlefield to compute grenade locations for input into the COMBIC model. Before, COMBIC users would have to manually compute the location of grenade detonations. These locations are dependent upon the location and orientation of the firing tubes in the discharger, the location and orientation of the discharger on the turret, the location and orientation of the turret

with respect to the hull, and the location and orientation of the hull with respect to the battlefield. In a simulation study, where an analyst might want to simulate the performance of an active defense system, the subtleties of component placement could be important. The augmentation improves the fidelity and resolution of the simulated smoke generation process.

3.2 MODTRAN

MODTRAN is a computer program that calculates the radiance and/or transmission for a specified path through the atmosphere. The transmission calculation use single parameter band models to compute the molecular line absorption of selected atmospheric species. Molecular continuum absorption, molecular scattering, and aerosol absorption and scattering are also included. The radiance calculations consider contributions from atmospheric self-emission, solar and/or lunar radiance single scattered into the path, direct solar irradiance through a slant path to space and multiple scattered solar radiance into path. The atmosphere is treated as a stack of up to 33 atmospheric layers. Physical parameters, ranging from pressure and temperature to molecular absorption and extinction coefficients are defined for each layer. As the path passes through each layer in the model, the atmospheric components of interest are computed and summed over the path and wavelength band. Several standard atmospheres are provided for the user. MODTRAN is used to correct the missile plume data for atmospheric losses that occurred during the missile test. The MODTRAN is used in conjunction with the DAY24 Generator model to account for the atmospheric losses for the user-defined foreign environments. The DAY24 Generator model supplies the necessary physical parameters for the atmospheric layers traveled by the LOS.

3.3 FLYOUT Model

The missile FLYOUT simulation is a full digital fly-out model of a threat antitank guided missile system against a single target (Herold, 1998). The simulation allows a user to input target position and speed along with missile launcher position. The missile is launched when the simulation is started. During the engagement, missile and target data, such as position and velocity, are stored on disk. At the end of the engagement, which is when the missile strikes or flies past the target, the radial and x, y, z miss distance is recorded. Target and missile trajectory data in graphical form can be generated. The engagement environment can be benign or include countermeasures. The modeling of the missile beacon and countermeasure does not include glint or reduction in intensity by obscurants. Future refinements will include modeling the variation in aspect angle of the missile caused by windspeed and direction. Future work will alleviate this problem.

4. Models in Development

4.1 MSPROP

The MSPROP model is the heart of the effort to propagate the missile plume signature from missile to receiver. MSPROP will modify the missile plume signature based upon atmospheric losses calculated for the specific location the user has chosen for engagement. High crosswinds

can increase the aspect angle of the missile. The missile and plume will then be viewed at a slight angle to the direction of flight. MSPROP will not initially compute the effects of these wind-induced changes in the missile's aspect angle on the missile plume signature. The effort for the current year is to enable MSPROP to work for a single threat missile. Future work will improve the model to address wind-induced effects on aspect angle and the effects of clutter. MSPROP will also access MODTRAN to determine the atmospheric losses for the LOSs from the tank to the missile. Atmospheric profiles will be developed this year for four sites of interest. Effects of weather will be included in fiscal year 99.

4.2. Day24 Generator Model

The purposes of the Day24 model is to take the (usually sparse) meteorological data obtained from world-wide climatological data bases and then "fill in" missing data that the user considers critical for their specific mission. In particular, the model can produce a best estimate of a full diurnal weather cycle based upon what data is available (which may include climatological studies from our own sources). The model also produces vertical profiles of parameters such as wind speed, temperature, relative humidity, and in some cases, aerosol concentrations. The vertical profiles begin at the (Earth) surface and extend as high as the mixing level that can vary from as low as about 100 meters at night to as high as 4000 meters during the day. A byproduct of the model is sub-surface temperatures down to a depth of approximately 1-meter into the soil. The model can also be used to drive optical turbulence and electromagnetic (em) clutter models as affected by meteorological variations. The model is semi-empirical and depends upon a good set of input for most accurate results. The model treats only time scales large in comparison to turbulent fluctuations although some turbulent parameters may be estimated from the output. The model is two-dimensional in that it treats time dependence and vertical variations (but not horizontal). The model assumes flat terrain in the immediate vicinity of the measurements and predicts only for the point of the measurements. Plans are in process for including complex terrain and adverse weather in future versions.

The model uses it's own tailored version of the surface energy balance for time evolution and the relatively new transient turbulence theory of transport for vertical profiles. The central feature of the model is the so-named surface energy balance and is illustrated in Figure 4.

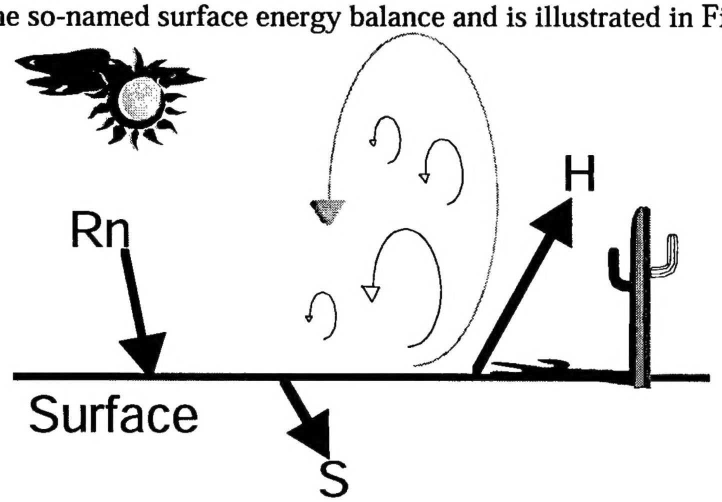


Figure 4 Sketch demonstrating the surface energy balance and turbulent reaction.

In the sketch of Figure 4 the various fluxes are (a) the net Radiative component, Rn, from sun, sky, and surface, (b) modeled air sub-surface heat flux S, and (c) the eddy heat flux, H, driven by the wind and turbulent exchange. If the fluxes balance then there is no change in surface temperature, otherwise the rate of change is governed by the degree of the imbalance. Further details of the mathematical approach can be found in Sutherland et. al, 1994. An example of the model as developed thus far is shown in Figure 5.

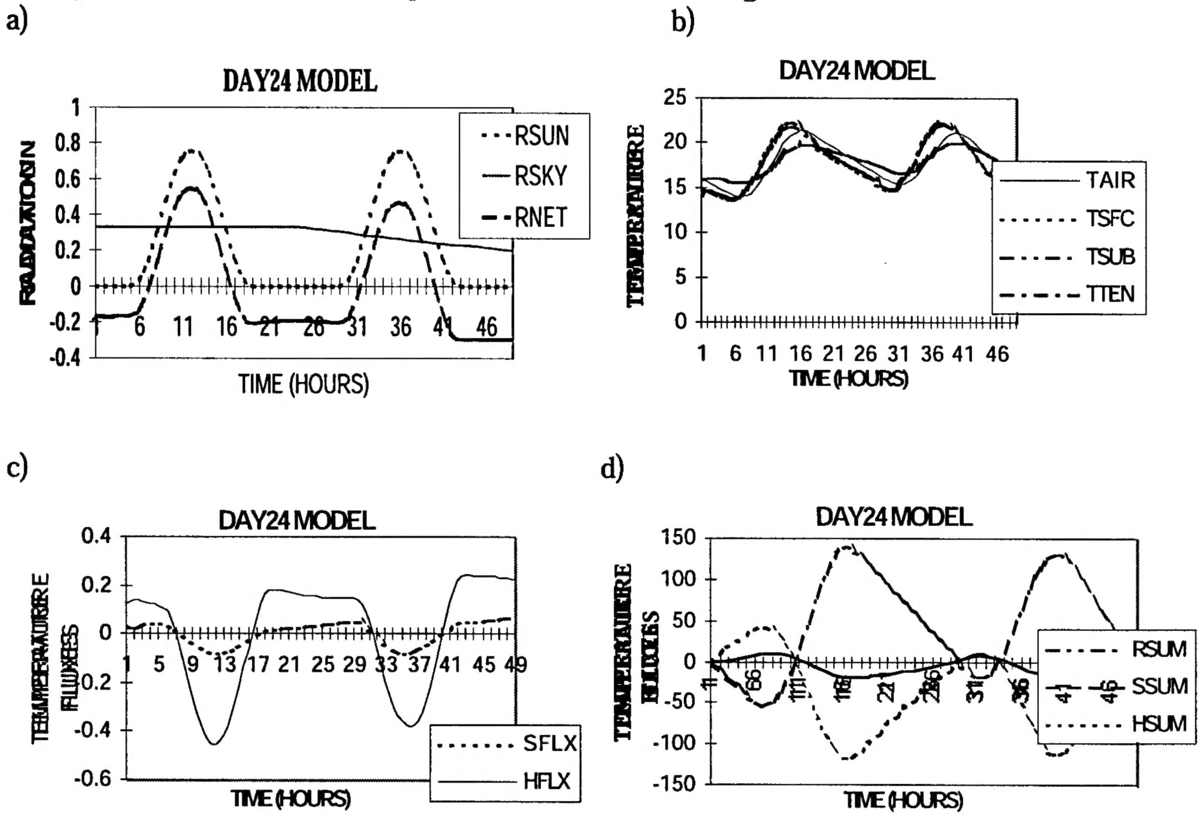


Figure 5a-d Example of DAY24 model showing two consecutive 24 hour periods; (a) driving radiation parameters, (b) air and subsurface temperature reactions, (c) instantaneous surface fluxes, and (d) cumulative surface fluxes.

The radiation (and wind) are the main drivers of the model and are shown in Figure 5a. The values here were made up for illustration to simulate the case of a fair weather day with constant windspeed (not shown) followed by a sharp decrease in wind at midnight and later an increase near midday. The radiation is comprised of the solar component (based upon sun angle and atmospheric attenuation) and the sky component (which is most influenced by cloud cover). For illustration we assumed the sky component to be constant the first day and linearly decreasing the second day. The solar component was modeled the same each day. The reaction as affecting the air and subsurface temperatures are shown in Figure 5b. Note the slow decrease in temperature to a minimum after 5 to 6 hours followed by the sharp increase as the solar component increases, and the subsequent flux changes shown in Figure 5c.

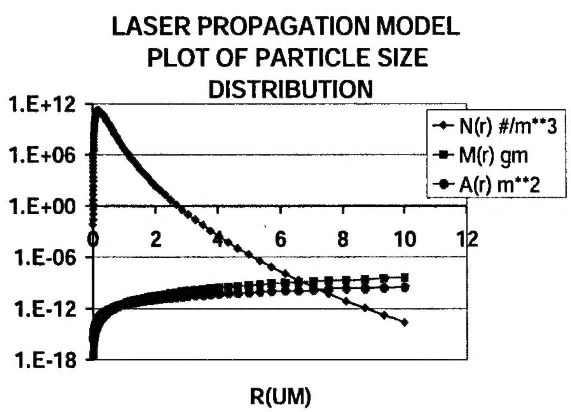
The maximum air temperature is reached after 15 hours and the maximum surface temperature is reached after 14 hours. Note after the end of the first day the overall increase of about 2 degrees for both the air and surface temperatures, indicating a net increase in input

energy. The second day is similar to the first except that the sky component of radiation is allowed to decrease at a constant rate. This is enough to return the final air and surface temperature to their original values of 16 and 14 degrees respectively, indicating a net energy input near zero for the two day period. This is also apparent from the cumulative fluxes shown in Figure 5d which shows a net increase of about 1.16 watts/day after the end of the first 24 hour period but near zero after the full two day cycle.

Our current plans call for further work on the model, the most significant being the further development to the transilient turbulence algorithm to model vertical profiles and the mixing height. With these so determined then other electro-optical parameters, such as the index of refraction structure parameter, C_n^2, optical turbulence can be estimated using techniques developed in Yee et. al., 1993. We also have fieldwork currently underway to verify the model and develop methods for optimizing with best fits to field measurements.

4.3 Laser Propagation Model

The Laser Propagation model is intended as a tool to evaluate laser-warning receivers and laser designator systems as affected by conventional military obscurants such as fog oil. This computer-based model uses ray tracing and Monte Carlo techniques similar to those used in BRLCAD (Butler, and Tannebaum, 1998). The model is capable of providing both the directly transmitted radiation and multiple scattering from all directions inside an obscurant cloud. The model treats the obscurant as a finite array of small volume elements, or voxels, assuming the extinction and scattering properties to be know from first principles optical models. An example of the scattering properties for fog oil is shown in Figure 6a.



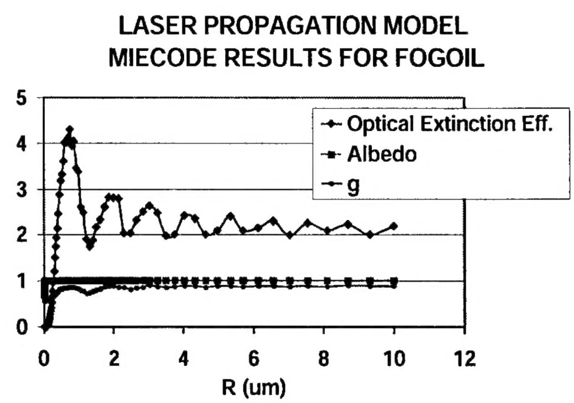


Figure 6. Plot of particle size distribution (a) and corresponding single particle optical properties (b) of fog oil used in the Laser Propagation Model.

The plots in Figure 6 were generated with the ARL model MIECODE (Yee, et. al.) which is based upon the Mie theory of scattering for spherical particles. The curves on the left show the particle number density, N(r), particle mass, m(r), and geometrical cross-section, A(r), as a

function of particle size (radius). Note the peak in the spectrum at about r=0.187 microns, which is very near the geometrical, mean radius, which is 0.215 microns for this case. The results here were generated assuming a log-normal particle size distribution of width σ=1.45 which is typical of measured values for fog oil. The plots on the right were generated with the MIECODE model for a laser wavelength of 1.06 microns and show the optical extinction efficiency, Q_e, albedo, w_o, and phase function asymmetry parameter, g, as a function of particle radius. Note the general monotonic increase in the extinction efficiency at small values of r and the leveling off to a value near 2 at higher r. Note also the fine scale "ripple" characteristic of Mie scattering giving efficiencies as high as 4.29 at r=0.756.

The optical extinction efficiency when multiplied by the geometrical cross-section gives what is conventionally called the optical extinction cross-section which is used in the Laser Propagation Model uses to determine a probability of a photon interaction in the Monte Carlo routine. If the interaction does occur then the albedo determines the probability of either scattering or absorption. If the photon is scattered, then the angle of scattering is determined by the phase function asymmetry parameter using the Henyey-Greenstein formulation. These probability rules are used in a ray-tracing algorithm employing several thousands of photon trajectories to arrive at the total reaching a given point. The model is also time dependent and can address pulse stretching as well as directional scattering. This year the effort is focused on creating a model that can propagate energy through a simple fogoil smoke cloud. Next year the effort will be focused on extending this capability to other obscurants, integration with atmospheric aerosols (i.e. rain, haze, dust) and using scaling techniques to reduce the size of the data base this model creates.

5. Scenarios

Appropriate met observation data will be collected for four sites and categorized according to adverse effects on dominant EM and other sensor systems. Miniature smoke vignettes will be created for the four chosen sites representing both friendly and foreign smokes (where appropriate). MSPROP will be run for the prevalent met conditions at the four sites and for the established smoke in the smoke vignettes. Self-defense smokes like the M76 IR grenades and L8A1 grenades will then be "played". MSPROP will then be run again to determine if these self-defensive smoke grenades will interfere with the MWR ability to track the missile plume. A scenario consisting of only vehicle dust will also be developed. A series of both threat based and survivability suite sensor predictions will be developed based on that data.

6. Summary

The TTM effort entitled "Atmospheric Effects for Ground System Hit Avoidance" will be a useful tool that in conjunction with simulation or software algorithms of MWR and LWR can provide a useful tool in measuring atmospheric and obscurants effects on the warning receivers. These effects in turn can affect the Commander's Decision Aids. The total package, integrating meteorological and systems effects, will offer higher fidelity alternatives for current simulations available to the systems analysis community.

7. References

Anderson, L., Roger Holmack, Thelma Chenault, and Joseph Churchman, 1998, "Making Obscurant Analysis Productive", Proceedings of the 1998 Smoke Obscurant Symposium, Edgewood at Aberdeen Proving Ground, MD (In Press).

Ayres, S.D., and S. DeSutter, 1993, "Combined Obscuration Model for Battlefield Induced Contaminants (COMBIC) Users Guide", U.S. Army Research Laboratory.

Butler, L.A., P.J. Tannebaum, 1998, Private Communication, U.S. Army Research Laboratory, Survivability Lethality Analysis Directorate.

Cundiff, C.R., 1998, Private Communication, U.S. Army Research Laboratory, Survivability Lethality Analysis Directorate.

Herold, C. R., 1998, Private Communication, U.S. Army Research Laboratory, Survivability Lethality Analysis Directorate.

Johnson, D.J. and W.G. Rouse, 1997, "The Vehicle Smoke Protection Model and Cloud Density Visualization Utility", OMI-598, Optimetrics, Inc., Forest Hill, MD.

Sutherland, R.A., Yee, Y.P., and R.J. Szymber, 1994, "Transient Turbulence, Radiative Transfer, and Owning the Weather", Proceedings of the 19945 Battlefield Atmospherics Conference, White Sands Missile Range, NM.

Yee, Y.P., Sutherland, R.A., Rachele, H. and A. Tunick, 1993, "Effects of Aerosol-Induced Radiative Interactions on Stability and Optical turbulence", Proceedings of the Society of Photo-Optical Instrumentation Engineers.

Sutherland, R.A. and W.M. Farmer, 1996, "Second Workshop on the Electromagnetic of Combat Induced Atmospheric Obscurants", ARL-TR-832.

PLEASE CHECK THE APPROPRIATE BLOCK BELOW:

-AO # ____________

☐ ____________ copies are being forwarded. Indicate whether Statement A, B, C, D, E, F, or X applies.

☒ DISTRIBUTION STATEMENT A:
APPROVED FOR PUBLIC RELEASE: DISTRIBUTION IS UNLIMITED

☐ DISTRIBUTION STATEMENT B:
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES ONLY; (Indicate Reason and Date). OTHER REQUESTS FOR THIS DOCUMENT SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ DISTRIBUTION STATEMENT C:
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES AND THEIR CONTRACTORS; (Indicate Reason and Date). OTHER REQUESTS FOR THIS DOCUMENT SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ DISTRIBUTION STATEMENT D:
DISTRIBUTION AUTHORIZED TO DoD AND U.S. DoD CONTRACTORS ONLY; (Indicate Reason and Date). OTHER REQUESTS SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ DISTRIBUTION STATEMENT E:
DISTRIBUTION AUTHORIZED TO DoD COMPONENTS ONLY; (Indicate Reason and Date). OTHER REQUESTS SHALL BE REFERRED TO (Indicate Controlling DoD Office).

☐ DISTRIBUTION STATEMENT F:
FURTHER DISSEMINATION ONLY AS DIRECTED BY (Indicate Controlling DoD Office and Date) or HIGHER DoD AUTHORITY.

☐ DISTRIBUTION STATEMENT X:
DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES AND PRIVATE INDIVIDUALS OR ENTERPRISES ELIGIBLE TO OBTAIN EXPORT-CONTROLLED TECHNICAL DATA IN ACCORDANCE WITH DoD DIRECTIVE 5230.25, WITHHOLDING OF UNCLASSIFIED TECHNICAL DATA FROM PUBLIC DISCLOSURE, 6 Nov 1984 (Indicate date of determination). CONTROLLING DoD OFFICE IS (Indicate Controlling DoD Office).

☐ This document was previously forwarded to DTIC on ____________ (date) and the AD number is ________________.

☐ In accordance with provisions of DoD instructions, the document requested is not supplied because:

☐ It will be published at a later date. (Enter approximate date, if known).

☐ Other. (Give Reason)

DoD Directive 5230.24, "Distribution Statements on Technical Documents," 18 Mar 87, contains seven distribution statements, as described briefly above. Technical Documents must be assigned distribution statements.

Tom Minnich
per phone call with J. Camp 10/22/98
Authorized Signature/Date

AFRL/FSD
2241 Avionic Circle
Wright -Patterson AFB, OH 45433-7318
John Camp
Print or Type Name

937 255 2164 3562
Telephone Number